REMEDIATION OF DENSE NON-AQUEOUS PHASE LIQUID CONTAMINATION IN AQUIFERS USING SEAR-NB

The Problem

Groundwater contamination by chlorinated solvents to plague sites in both the public and private sector worldwide. Maximum concentration limits (MCLs) of these dense, non-aqueous phase liquids (DNAPLs) are several orders of magnitude lower than their groundwater solubility, this limiting the ability of classic pump and treat methods for aquifer restoration. Therefore, a residual DNAPL will continue to be a source of groundwater contamination for decades.

The Solution

The INEEL has developed a technology to remove DNAPLs from contaminated aquifers: Surfactant-Enhanced Aquifer Remediation at Neutral Buoyancy, or SEAR-NB (patent pending). This technology is an improvement over pump and treat by orders of magnitude in both cleanup time and cost. Remediation can be tailored to minimize buoyancy effects through the use of surfactants, alcohol, and polymers. This technology provides the ability to predict and manipulate the vertical migration of contaminants and, therefore, removes undo concern over uncontrolled vertical migration, even in aquifers not underlain by a clay aquiclude.

In recent years, surfactant-enhanced aquifer remediation (SEAR) has received attention as an emerging technology for DNAPL remediation. SEAR was recently demonstrated to be effective at remediating an aquifer contaminated with DNAPLs at Hill Air Force Base (UT) OU-2. In excess of 99% of the DNAPL was extracted from the aquifer using SEAR.

Despite the success of this field demonstration, there is a perceived limitation of SEAR. A confining aquitard must be present below the contamination to prevent vertical migration of the DNAPL. The technology developed at the INEEL, SEAR-NB, is an extension of SEAR technology. By using SEAR-NB, vertical migration of the contaminants can be minimized. The resulting neutral buoyancy displacement can, therefore, be performed even in cases where no confining aquitard exists. This is the only technology that addresses active DNAPL remediation in such environments.

Our research has shown that the forces acting on SEAR process, both buoyancy (arising from density differences) and the horizontal driving forces (arising from injection and extraction) can be manipulated, and unfavorable density differences can be overcome. In addition to manipulating and minimizing the vertical migration of the contaminant, our work has demonstrated that we can predict its vertical migration. Wells can be screened to ensure full capture of the plume, and DNAPL remediation can be achieved in aquifers that have no underlying aquitard using SEAR-NB.

Benefits of SEAR-NB

Benefits of the SEAR-NB process arise from the increases in effective solubility of the DNAPL using surfactants. Solubility of TCE in a surfactant solution is given in Table I and is compared with its solubility in groundwater (i.e. for pump and treat). Cleanup time reduction is proportional to the increase in solubilization. Thus, a cleanup operation that required decades using pump and treat could be performed in months using SEAR-NB. Furthermore, the surfactants, alcohol, and polymers are food additives and do not contribute to the contamination of the aquifer or create an additional waste stream that must be treated. A further benefit of SEAR-NB is that, for the first time, active remediation of DNAPLs can be pursued in aquifers without an underlying clay layer. There is no technology currently available that can safely remediate DNAPLs under these conditions except SEAR-NB.

Table I. Comparison in Solubilization ratios and Cleanup Times for TCE Between Pump-and-Treat and SEAR-NB

Technology	Solution	Solubility	Cleanup Time Ratio
Pump-and-Treat	Groundwater	1100 ppm	1 (baseline)
SEAR-NB	Groundwater + 4 wt.% surfactant + 8 wt.% isoproponol	35,000 ppm	0.03

Cost of Cleanup

Another benefit of SEAR-NB is the reduction in aquifer remediation cost, which results directly from the enhanced solubilization of DNAPL compounds by surfactants. These cost benefits are obtained from a reduction in Management and Operating costs, primarily due to the decrease in cleanup time. Estimated costs of the only two competing technologies are given in Table II.

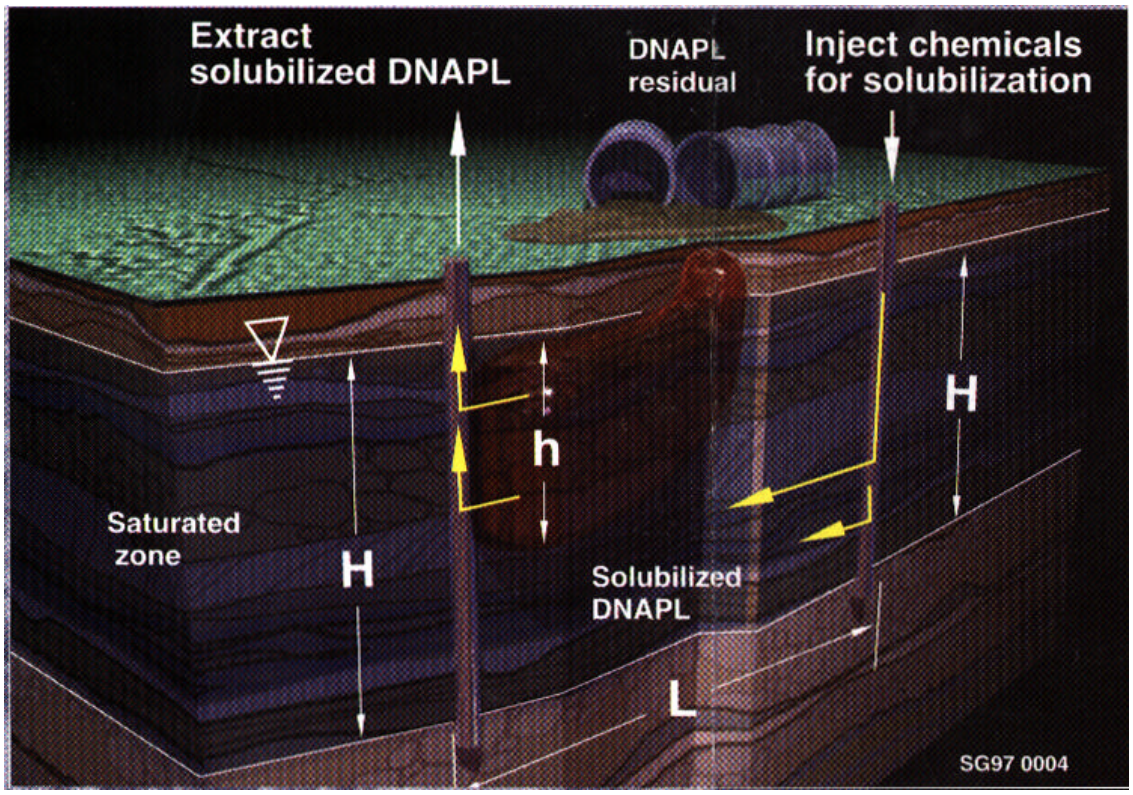
Table II. Example of Cleanup time and Cost

Technology	Cleanup time	Cost
Pump-and-treat	30 years	$30,000/gal. DNAPL removed
SEAR-NB	11 months	$800/gal. DNAPL removed

The Next Generation – SEAR-NB

Without active remediation of DNAPL-contaminated aquifers, the source of contamination will exist for many decades. In aquifers not underlain by a clay barrier preventing vertical flow, SEAR-NB offers the only opportunity for active aquifer restoration. Using SEAR-NB, the actual vertical migration of the solubilized DNAPL

compounds can be predicted and minimized, and wells screened sufficiently deeply to ensure full capture of the plume. Of the more than 300,000 contaminated sites world wide, many would benefit from the application of SEAR-NB.



Migration of the solubilized DNAPL can be predicted and minimized to avoid uncontrolled vertical migration. Variables in the figure are: L = well spacing, H = overall aquifer thickness, h = actual vertical movement of solubilized DNAPL.

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